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Fabrication of TaC-HfC ceramics for ultra-high temperature applications

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Fabrication of TaC-HfC ceramics for ultra-high temperature applications

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TaC-HfC system and Sintering

- Compounds in the TaC-HfC system have extremely high melting points (4TaC-1HfC: 3990 ℃; 5TaC-1HfC: 3950 ℃; 3TaC-1HfC: 3890 ℃)
- Ta_4HfC_5 has the highest melting point of any compound.
- Using commercial TaC and HfC powders we sintered different compounds using SPS (Spark Plasma Sintering) and Pressureless Sintering.
- Three different compositions were selected (4TaC-1HfC, 6TaC-1HfC and 5TaC-1HfC) with the addition of 0.5% wt. of C and B_4C as sintering aids. Uniaxially pressed at 3 MPa and sintered at 2100 ℃ for 20 min.at 60 MPa.
- Samples of 4TaC-1HfC with addition of 0.5% and 1% wt. of $MoSi_2$, $TaSi_2$, HfO_2 and cold isostatically pressed at 350 MPa were sintered at 1950, 2100 and 2380 ℃.

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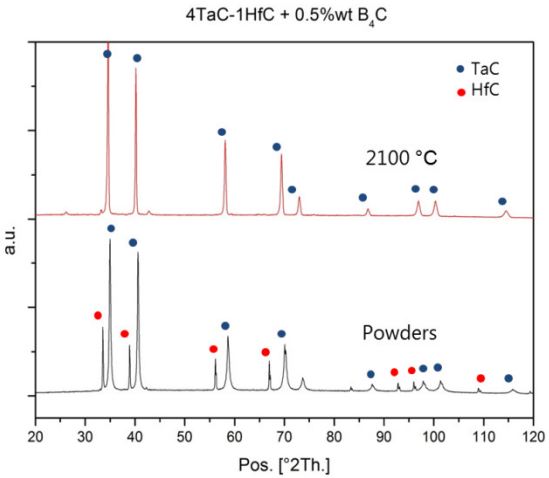
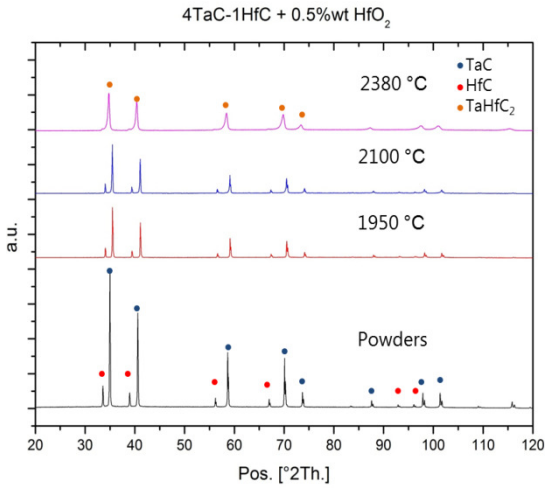
Results

Sample	Relative Density %
4TaC-1HfC + 0.5% C	92.2 ± 2.5
4TaC-1HfC + 0.5% B_4C	97.0 ± 0.9
6TaC-1HfC + 0.5% C	92.5 ± 3.6
6TaC-1HfC + 0.5% B_4C	96.3 ± 1.0
5TaC-1HfC + 0.5% C	88.3 ± 2.5
5TaC-1HfC + 0.5% B_4C	88.1 ± 2.2



- Nearly fully dense ceramics were achieved with SPS (~97%).
- Ta-Hf-C compounds were not found.

Sample	Green Density %	Sintering Temp. °C	Relative Density %
4TaC-1HfC + 0.5% TaB_2	51.9%	1950	75.3% ± 8.5
	53.7%	2100	76.0% ± 5.3
	54.0%	2380	84.0% ± 3.3
4TaC-1HfC + 1% TaB_2	53.1%	1950	72.9% ± 3.0
	52.9%	2100	86.2% ± 9.4
	54.3%	2380	83.2% ± 3.9
4TaC-1HfC + 0.5% $MoSi_2$	48.6%	1950	88.7% ± 3.4
	53.7%	2100	89.0% ± 4.1
	54.4%	2380	85.1% ± 5.2
4TaC-1HfC + 1% $MoSi_2$	53.5%	1950	84.0% ± 5.0
	54.1%	2100	83.4% ± 7.9
	53.8%	2380	82.6% ± 1.9
4TaC-1HfC + 0.5% HfO_2	53.6%	1950	87.1% ± 2.4
	53.8%	2100	82.5% ± 9.7
	54.1%	2380	93.9% ± 2.4
4TaC-1HfC + 1% HfO_2	55.9%	1950	86.8% ± 2.4
	54.2%	2100	86.1% ± 3.5
	54.3%	2380	90.7% ± 3.2



- Only samples with HfO_2 and 2380 ℃ achieved a density over 90%.
- Formation of Ta-Hf-C compounds was achieved with sintering at 2380 ℃.

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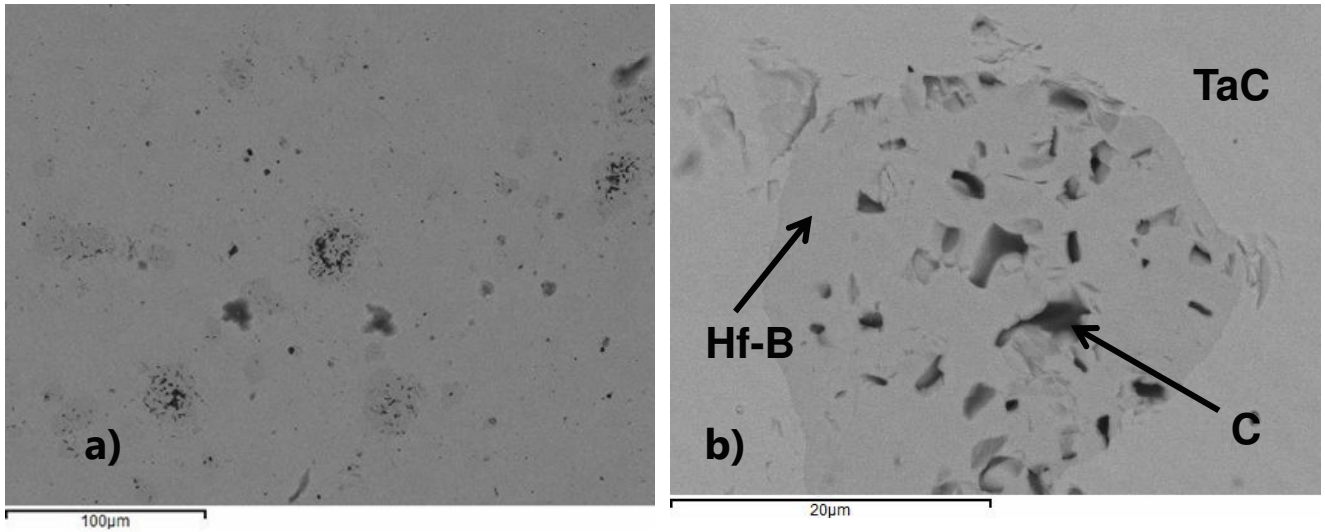
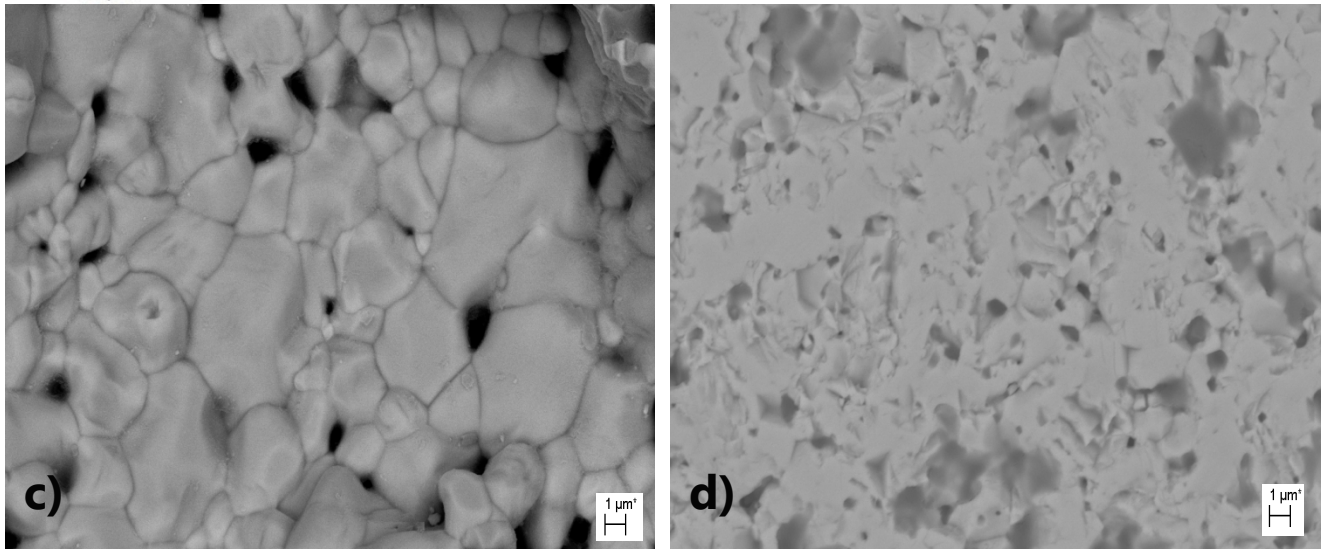
Microstructure

SPS



a) and b) at 2100 °C

Presureless Sintering



c) 2100 °C

d) 2380 °C